An imaging *K*-band survey – II: The redshift survey and galaxy evolution in the infrared

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ABSTRACT

We present further results from an imaging K-band survey of $552\,\mathrm{arcmin}^2$, complete to a 5σ limit of $K \simeq 17.3$. This paper describes a redshift survey of 124 galaxies, and addresses the colours of faint galaxies and the evolution of the K-band luminosity function. The optical-to-infrared colours are consistent with the range expected from synthetic galaxy spectra, although there are some cases of very red nuclei. These may possibly be attributed to either extinction or metallicity gradients. Our data show no evidence for evolution of the K-band luminosity function at $z < 0.5$, and the results are well described by a Schechter function with $M_K^* = -22.75 \pm 0.13 + 5\log_{10} h$ and $\phi^* = 0.026 \pm 0.003\,h^3\,\mathrm{Mpc}^{-3}$. This is a somewhat higher normalization than has been found by previous workers, and it removes much of the excess in faint K and b_J counts with respect to a no-evolution model. However, we do find evidence for evolution at $z > 0.5$: M_K^* is approximately 0.75 mag. brighter at $z = 1$. This luminosity evolution is balanced by a reduced normalization at high redshift: the total luminosity density is required to be approximately constant in order not to exceed the faint counts. The overall evolution is thus *opposite* to that expected in simple merger-dominated models; we briefly consider possible interpretations of this result.

1 INTRODUCTION

The development of two-dimensional near-infrared detectors has finally made it possible to survey substantial areas of the sky at these wavelengths to cosmologically interesting depths. Two surveys covering more than several hundred arcmin^2 of the sky have recently been completed: the Hawaii Surveys described by Gardner et al. (1993), Cowie et al. (1994) and Songaila et al. (1994), and the Edinburgh Survey described by Glazebrook et al. (1994 – hereafter referred to as Paper I).

This is the second paper concerning our K-band redshift survey covering $552\,\mathrm{arcmin}^2$. Paper I discussed in detail the construction and calibration of this survey, and the associated optical CCD imaging for all the fields. It also presented our results for the K-band star and galaxy counts. This paper is concerned with a K-selected redshift survey and the resulting colour-redshift and luminosity function analyses.

A study of galaxy evolution in the near infrared is of great interest. Historically the main evidence for bulk evolution in samples of field galaxies derives from optical surveys, culminating in the 'faint blue galaxy problem': number-magnitude counts over $15 < b_\mathrm{J} < 28$ are much steeper than predicted by a non-evolving model (see Ellis 1990 for a review). Optically-selected redshift surveys have shown this

faint excess to be a population of very blue objects, evolved mainly in density rather than blue luminosity (Broadhurst et al. 1988; Colless et al. 1991 and Glazebrook et al. 1995a). Various models have been proposed to explain this observation: Koo et al. (1993) have proposed radical alteration of the local luminosity function by introducing a large dwarf galaxy component. Similarly, Cowie et al. (1991) and Babul & Rees (1992) have proposed a model in which the blue population consists of a new population of dwarf galaxies undergoing an initial starburst at $z \sim 0.4$ and fading to invisibility by the present day. A different model has been proposed by Broadhurst, Ellis & Glazebrook (1992: BEG) and Rocca-Volmerange & Guiderdoni (1990) in which a large amount of galaxy-galaxy merging has occured in the field population in the recent past, as might be expected in CDM-like theories in which structure grows by hierarchical growth (e.g. Carlberg 1992). However, the most recent possible explanation is the simplest: that bright surveys are not sufficiently sensitive to galaxies of low surface brightness (McGaugh 1994). This suggestion of incompleteness in the bright counts accords with the work of Metcalfe et al. (1991 & 1994), who have argued that the fainter data for $17 < b_\mathrm{J} < 22$ can then be explained by a high local normalisation to the luminosity function.

In view of these controversies, an independent approach to galaxy evolution is clearly attractive, and the K band is

in many ways preferable to the optical. The optical work samples the rest-frame UV at $z \gtrsim 0.3$, so that the optical luminosity depends sensitively on the rate of star formation. Also, most of the optical light in galaxies comes from massive OB stars which are only a small fraction of the total stellar mass of the galaxy. Thus a dwarf galaxy undergoing a powerful starburst can attain a b_J luminosity identical to that of a giant spiral or elliptical galaxy evolving quiescently. Since galaxies at high redshift are unresolved from the ground, these very dissimilar systems can be indistinguishable in faint optical imaging data.

In contrast, the near-infrared light in galaxies is produced by giants drawn from the population of old evolved stars which dominate the stellar mass. Moreover the K-correction is much better defined for a K-band sample than in the optical. This is again because the spectral slope in the optical is dominated by the star-formation rate; thus spiral and elliptical galaxies have blue K-corrections that differ by 1 magnitude at $z = 0.5$. The observed morphological mix will therefore change greatly with redshift, complicating the interpretation. In contrast galaxy colours in the near-infrared are dominated by old stars and are uniform across Hubble types (Aaronson 1978), thus yielding a constant morphological mix.

A no-evolution prediction showed that we expected to see galaxies out to $z = 1$ at $K = 17$ (Paper I), the redshift of interest for evolution, so this motivated us to carry out a redshift survey of our Paper I objects. Additionally the colour-redshift relation allows us to test generic properties of spectral evolution models independently of the luminosity function.

The plan of this paper is as follows. Section 2 discusses the spectroscopic observations and the data reduction procedures used to obtain the redshifts and Section 3 describes how we use these to obtain revised K magnitudes in metric apertures for our galaxies. In Section 4 we discuss the details of the faint galaxy colours and how they depend on redshift. Section 5 details our luminosity function analysis and in Section 6 we compare our results with other work on galaxy evolution. Finally the results and conclusions are summarized in Section 7.

Throughout, we scale results to the usual dimensionless Hubble parameter: $h \equiv H_0/100 \,\mathrm{km\,s^{-1}Mpc^{-1}}$. Unless otherwise stated, we assume a cosmological model with $\Omega = 1$ and zero cosmological constant.

2   SPECTROSCOPIC OBSERVATIONS

Our redshift survey was carried out in several observing runs on the Anglo-Australian Telescope and the William Herschel Telescope in La Palma over the period 1990–1992. We used the Autofib multi-fibre spectrograph (Parry & Sharples, 1988) for the brighter objects ($R < 19$), long and multi-slit spectroscopy using the ISIS spectrograph for intermediate magnitudes ($18 < R < 20$) and the LDSS1 (Wynn & Worswick 1988) and LDSS2 (Allington-Smith et al. 1994) multi-slit spectrographs (both of which have a very similar design) for the very faintest objects with ($R \gtrsim 20$).

We followed standard procedures for debiasing, flatfielding and stacking the data and extracting spectra. Our final spectra were determined to be limited by Poisson sky noise. For our faintest objects at $R = 21$–22, 9000s integrations were required to give $> 90\%$ completeness in identifications. We determined the identifications manually by carefully examing each individual spectrum, and also used cross-correlation with galaxy templates following Tonry & Davis (1979). This confirmed our manual results, but proved no more powerful at extracting redshifts from faint noisy spectra than the manual method. In our initial spectroscopic runs we observed objects which we had classified as stars from the image profiles in our broad-band CCD images; it turned out our classification was very reliable (for the statistics see Paper I) and so we subsequently observed only objects classified as galaxies. Our final redshift catalogue consists of 124 galaxies and is presented in Table A1 of the appendix.

As a result of an observing programme which evolved through a succession of spectrographs of increasing sensitivity, our dataset was acquired in a somewhat heterogeneous manner. An ideal approach would have been to define in advance a target sample which was randomly selected from the parent catalogue to contain uniform numbers of objects per K magnitude bin, and continue observing until redshifts for all the target objects were obtained. In practice, the targets we could observe were limited by scheduling of observing runs and by weather. The initial runs lacked sufficient sensitivity to yield redshifts for the reddest objects, and so there were initially many cases of inconclusive spectra. As the survey progressed and more sensitive spectrographs became available, we were able to obtain successful spectra representative of the previous class of failures, although we could not in all cases observe the identical objects. Our final spectroscopic runs were therefore used to ensure that the redshift sample was as statistically representative as possible. The $(R - K, K)$ colour-magnitude diagram was inspected, and targets were chosen randomly to fill in under-sampled parts of the $(R-K, K)$ plane. The success of this strategy may be judged from Figure 1a, where we compare the $(R - K, K)$ distribution of the objects with redshifts with that for all the galaxies. We are very close to the desired uniform sampling of $R - K$ at given K, down to $K = 17.25$; fainter objects were not considered. The only areas where the eye suggests a low sampling are at $(K, R - K) \simeq (17.0, 4.5)$ and $(K, R - K) \simeq (15.5, 2.0)$. The former case reflects the difficulty of obtaining spectra for very faint objects, and is quantified by the colour-dependent weights discussed in Section 5.1. Conversely, any suggestion of bias against the blue objects is merely a random fluctuation. Most spectra come from our October fields, and redshifts were obtained for the bluest objects in these fields; however, the March fields contain a few galaxies that are bluer than any in the October fields.

Since not all spectra yielded a redshift, it is important to be sure that the omitted objects do not bias the results. Our early runs on less sensitive spectrographs had many inconclusive spectra, but this mainly allowed us to establish empirically the integration time needed for an object with a given R-band magnitude. For each spectroscopic run, we therefore defined a target integration time based on the R-band magnitude. For an the different instruments involved, this corresponded to a limiting magnitude in 10,000s integration of approximately $R = 19.0$ (Autofib); $R = 21.0$ (LDSS1); $R = 20.8$ (ISIS); $R \gtrsim 22.5$ (LDSS2). This re-

sults in 16 objects which satisfied our integration-time criteria based on their R magnitude, but for which no redshift was obtained. The locations of these objects on the colour-magnitude plane are shown in Figure 1b. In almost all cases, the objects were within 0.5 mag. of the effective optical limit for the instrument involved, and so it is plausible that they are simply low-s/n versions of the successful spectra, a selection of which are shown in Figure A1 in the appendix. Moreover it is clear from Figure 1b that there is no significant bias in colour or magnitude with respect to either the spectroscopically identified galaxies or the larger sample of image-classified galaxies. Given this and the small number of such objects, we believe it is reasonable to assume that the redshift distribution is not biased by their omission from the sample. Conversely, as in any spectoscopic sample, there are also a small number of identified galaxies *fainter* than our nominal limits: these are also shown in Figure 1b. There are only 8 of these (numbers 77, 118, 132, 190, 316, 333, 362, 364); again they are within 0.5 mags of our completeness limits and they lie in typical locations in the (K, z) diagram; their inclusion makes no significant difference to our subsequent analyses.

In summary, our spectroscopic sample contains 124 of the 335 galaxies in the imaging survey of Paper I. Most of our redshifts (119) are from the October fields, which contain a total of 201 galaxies, and we therefore have 59% sampling in this region. Furthermore, the selection of objects has been adjusted so as to give a representative coverage of the $(R - K, K)$ plane (apart from a known reduced sampling at faint K). Our sample should be statistically representative of the infrared galaxy population.

Figure 2 shows the fundamental data in the form of the redshift-magnitude plane. It is interesting to note that substantial redshifts are attained at relatively bright magnitudes. This observation already anticipates one of our principal conclusions: that 'merger' models which postulate a faint characteristic luminosity at high redshift are difficult to reconcile with our data.

3 APERTURE CORRECTIONS

An important issue not fully explored in Paper I or by Gardner et al. (1993) is the issue of aperture corrections to the data. The majority of our data were measured through a 4-arcsecond diameter aperture, although some (the March fields) used 8 arcseconds. An aperture of about 6 arcsec was used for most of the Hawaii work (see Gardner 1992). In their recent paper on the K-band luminosity function, Mobasher et al. (1993) corrected all their data to a standard isophotal aperture based on the optical light profiles of their galaxies. The metric aperture involved varied, but was typically $20 - 30 \ h^{-1}$ kpc, which would only correspond to our 4 arcsec aperture at redshifts of $z \simeq 1$. Our magnitudes are thus systematically fainter than those defined by other workers; how much difference does this make?

With redshifts secured we are now able to remeasure magnitudes through metric apertures; we will use a standard aperture of $20 \ h^{-1}$ kpc, which should be close to total for most galaxies and is a typical diameter for local measurements. For large apertures ($\gtrsim 10''$) our K magnitudes start to become unreliable due to noise and flat-field effects (due to the small size of the IRCAM detector). We therefore

follow the K growth curves out to where they turn over, or become too noisy ($\Delta K < 0.2$); beyond this we adopt the growth curve for the same galaxy from the corresponding R band CCD image. This is much better defined out to very large apertures. Figure 3 shows the difference between the original 4 arcsecond K magnitudes and the $20 \ h^{-1}$ kpc magnitudes as a function of redshift for galaxies for which a $20 \ h^{-1}$ kpc magnitude is directly measurable from the growth curves. As expected the low-redshift galaxies are systematically too faint, by up to 1 mag.

We might expect the growth in metric luminosity to be well parameterised following the approach of Gunn & Oke (1975) as:

$$L(< r) \propto r^{\alpha}. \tag{1}$$

For brightest cluster galaxies, $\alpha \simeq 0.7$ (Schneider et al. 1983), but lower values are more appropriate for field galaxies in general. For the sample of Mobasher et al. (1993), typical effective values are $\alpha \simeq 0.4$, and this is consistent with the Hawaii data (Gardner 1992). We would expect such a power-law profile to be valid provided it is not assumed to hold over too large a range of scales. Our maximum redshift is 0.8, and all but 2 have $z > 0.06$; the range of proper diameters corresponding to our 4 arcsecond apertures is thus 3.2 to 16.5 h^{-1} kpc. Even over this large range, exponential profiles ($r_{\text{scale}} = 3h^{-1}$kpc) and $r^{1/4}$ profiles ($r_{\text{eff}} = 4h^{-1}$ kpc) deviate from the power-law model at only at the $\simeq 0.2$ magnitude level. We plot the $r^{0.4}$ prediction in Figure 3; it is an excellent parameterisation of the data.

Our final metric magnitudes in K and R are given in Table A1. We carried out luminosity function analyses using both these values and those predicted from the 4-arcsec data using the $r^{0.4}$ growth curve. The results were indistinguishable, as expected from the good agreement shown in Figure 3.

4 FAINT GALAXY COLOURS

We begin by looking at the optical–infrared colours of our data. This will allow us to assess the mix of Hubble types in this sample, as well as to test synthetic galaxy spectra, on which we will rely to K-correct the data in the luminosity function analysis.

For the colours we measure K and R magnitudes independently in $20 \ h^{-1}$ kpc apertures as in Section 3. Figure 4 shows the $R - K$ colours of the galaxies plotted against redshift. Objects dominated by emission features are plotted with a separate symbol. We compare the colours with those of the galaxy templates we used for the number count predictions in Paper I (from Rocca-Volmerange & Guiderdoni 1988; RVG), plotting the red envelope for a high-redshift 1-Gyr burst of star formation, which should provide an upper limit to the locus of elliptical galaxies. We also show the intermediate colour Sc type and the Im type, which should define the blue limit for galaxies on the Hubble sequence. For a K-selected survey the K-corrections are very similar (see Section 5.2) for all types and so the morphological mix should not change with redshift. It is evident from Figure 4 that the mix, as defined by colour, is indeed approximately unchanging and so unlike optical surveys we are not biased against high-redshift red galaxies.

We also consider the more recent GISSEL models of Bruzual & Charlot (1993). These use a more up-to-date library of stellar templates and compute with a more accurate isochrone synthesis technique. Particularly important for our application is that the infrared portions of the spectra are based on much more detailed data than the work of RVG. Figure 4 also shows the GISSEL version of the 1-Gyr burst, which makes a similar prediction for the red envelope, but is systematically slightly bluer than the RVG model. The latter seems in practice to be in better agreement with the data.

We note the existence of one object (ID #96) with very extreme colours ($z = 0.225$, $R - K = 5.7$). This object has an emission line spectrum and at this redshift the Paα line lies in the K window; could this contribute to the K flux? Given standard case B assumptions for hydrogen line ratios (Hummer & Storey 1987) Paα/H$\beta = 0.332$, and we estimate from the observed $H\beta$ flux that the line flux from Paα would be equivalent to $K = 27$. There would therefore need to be large amounts of extinction in order for line emission to be significant, but this is not indicated in the optical spectrum. This object merits further study.

Otherwise, the reddest galaxies are approximately consistent with the model red envelope to within observational error, with the possible exceptions of #109, #224 & #346. This was not the case with our first version of this diagram for 4-arcsecond aperture colours, which contained many galaxies with $z < 0.3$ much redder than the envelope, particularly at low redshift. This was initially puzzling, but it was eventually realized that this was an effect of colour gradients: at low redshifts, the 4-arcsecond apertures sample the galaxy nuclei only – and these are very red in some cases. The galaxies with particularly red nuclei, together with their redshifts and 4-arcsecond colours are: #224, #563, #406, #109, #392 and #334. $z = (0.063, 0.080, 0.121, 0.148, 0.153, 0.192)$, $R - K = (3.8, 3.7, 3.9, 4.0, 3.9, 4.0)$. Significant optical-infrared colour gradients in ellipticals were previously noted by Peletier et al. (1989). They find up to 0.6 mag of reddening in $V - K$ for a factor 10 in radius, and our results seem to be consistent with these more extreme values.

What is the cause of the red nuclei? Although galactic bulges are redder than disks, we still would not expect them to be redder than a 1-Gyr burst if the colours were due to the stellar populations. It is possible with the GISSEL code to choose various Initial Mass Functions, and it is interesting to ask if the results are robust, particularly for the red envelope. We find that stars with initial masses $> 2.5 M_\odot$ make negligible contributions at late ages (> 15 Gyr). Increasing the proportion of low mass stars by adopting a flatter IMF also makes little difference – doubling the fraction of stars below $0.3\,M_\odot$ only makes a difference to the curve at the 0.05 magnitudes level. We conclude that the choice of IMF has little influence on the red envelope of $R - K$ colours, as it is determined by the spectral energy distributions of $\sim$ solar mass stars. Peletier et al. attribute the reddening to metallicity gradients. This is certainly a plausible explanation for our results, although large amounts of dust in some nuclei remains a possibility (a screen with $A_V = 1.2$–1.3 mag. would be required to produce the observed $R - K$ excess). Low-level AGN are a third potential explanation, especially if they are heavily reddened. These extremely red galaxies merit detailed further examination to investigate these possibilities.

5   LUMINOSITY FUNCTION ANALYSIS

We now proceed to derive the K-band galaxy luminosity function from our data. We shall be particularly interested in the comparison between our results and those of Mobasher et al. (1993) and the Hawaii survey (Cowie & Songaila 1993; Cowie et al. 1995). The former was based on K-band observations of 95 B-selected galaxies, with completeness claimed to $K = 12.5$. The Hawaii sample consists of 262 redshifts, complete to $K \simeq 19 - 20$. In fact, our results turn out not to agree very well with either of these pieces of work, for what we believe are the reasons described below in Section 5.4.

5.1   Counts and incompleteness corrections

The longer integration times required mean that we were able to obtain fewer spectra for the fainter galaxies. Nevertheless, the redshift distribution at given magnitude should still be faithfully reproduced by our data, provided the range of colours at given K is properly sampled. We tested this by dividing the $(R - K) - K$ colour–magnitude plane into cells (using increments of 0.3 in K and 0.5 in $R - K$) and comparing the populations of these cells in our total and spectroscopic samples. This allows a colour-dependent weight to be deduced at given K magnitude. These weights were usually close to unity; setting them to exactly unity had no significant effect on the results below — the maximum change in M_K^* is only 0.02 mags and the effect on the resultant space densities is at the $\lesssim 10\%$ level. As the latter spans a factor of 100 in value it is not suprising that M_K^* is robust to such changes.

We now need to know the effective K-dependent incompleteness, and this may be deduced by comparing the number of galaxies in our spectroscopic sample as a function of magnitude with that expected from the overall number counts. A convenient analytical fit for these is

$$\frac{dN}{dK} \big/ \deg^{-2} = \frac{10^{0.75(K-12.1)}}{\left[1 + 10^{0.35(K-17.2)}\right]^{1.5}}, \tag{2}$$

which is a statistically acceptable best fit to the data from Paper I plus the Hawaii counts from Gardner, Cowie & Wainscoat (1993), and the data of Jenkins & Reid (1991), as shown in Figure 5 (this plot also includes the recent faint count data from McLeod et al. 1995 and Djorgovski et al. 1995). We have preferred to force the slope at bright magnitudes to the Euclidean value expected from the aperture correction: $N \propto 10^{\beta K}$, where $\beta = 1.2/(2 - \alpha)$ (where $L \propto r^\alpha$ is the analytic aperture correction derived in Section 3); any other slope would indicate strong local evolution if taken literally.

The corrections needed to achieve uniform 4 arcsecond magnitudes in Figure 5 are as follows. The Hawaii data (Gardner 1992) were measured in 6.3 arcsec apertures for the HMDS and HMWS surveys, but published with offsets of respectively -0.1 and -0.2 mags as a notional correction to total. We have removed these offsets and added a further 0.2 mag to correct to 4-arcsec measurements. The deeper

HDS was measured in 3.5 arcsec and a correction to 6 arcsec made on a field-to field basis. Since the individual corrections are not available, we have treated the published data as exact 6-arcsec measurements and added a correction of 0.18 mag. The deep data of Djorgovski et al. (1995) are in 5.4 arcsec apertures, and so need a correction of 0.13 mag. The deep data of McLeod et al. (1995) are focas magnitudes for which an aperture is not quoted; we have left them uncorrected. Lastly, for the 20 arcsec apertures used by Jenkins & Reid (1991), the correction to 4 arcsec predicted by our $r^{0.4}$ growth curve is 0.70 mag. This explains why their counts were clearly seen in Paper I to lie above those obtained by other workers. However, we do not expect a power law to apply over this range of radius; at faint magnitudes, apertures above 8 arcsec will be total. We have therefore applied the offset of 0.7 at $K = 15$, declining to 0.3 at $K = 19$. This should be correct to within about 0.1 mag.

Dividing the K counts in our spectroscopic sample by the average counts yields the effective completeness, shown in Figure 6. This stays close to unity up till about $K = 16$ and then falls to almost 0.1 in the $K = 17 - 17.25$ bin, which is the faintest bin that contains spectroscopic data. The completeness is significantly greater than 1 for $K \simeq 14.5$, and this reflects the use of some galaxies as positional references in constructing the sample (see Paper I). We shall use this incompleteness curve in the luminosity function analysis, assuming unit completeness for $K < 14$. Using a smoothed form of this figure makes no difference to the results.

We can now deduce the properties of a true flux-limited sample to $K = 17.25$ by appropriately weighting the fainter galaxies. Figure 7 shows both the raw and weighted redshift histograms for our sample. The observed median redshift of 0.24 increases to 0.35 after weighting.

5.2 K-corrections

In order to obtain absolute magnitudes, we require a knowledge of the luminosity distance D_{L}, the K-band K-correction $K(z)$, and the aperture correction $A(z)$:

$$M(z) = m - 5 \log_{10}[D_{\mathrm{L}}/10 \text{ pc}] - K(z) + A(z). \tag{3}$$

For simplicity, we shall throughout quote absolute magnitudes assuming $h = 1$ for the Hubble parameter. The aperture correction converts the observed aperture magnitudes to some proper diameter. As stated above, we shall choose this to be

$$D_0 = 20h^{-1} \text{ kpc}, \tag{4}$$

so that the aperture correction is given in terms of angular-diameter distance $D_{\mathrm{A}}(z)$ as

$$A(z) = \log_{10}[\theta D_{\mathrm{A}}(z)/20h^{-1} \text{ kpc}], \tag{5}$$

where θ is our standard angular diameter of 4 arcsec.

One of the advantages of the infrared waveband is that the K-corrections are very similar for all classes of galaxy, reflecting the dominance of giants in this waveband. The widely different amounts of star formation in different Hubble types only affects the spectra at wavelengths somewhat shorter than 1μm. This is illustrated in Figure 8, which shows theoretical K-corrections taken from the evolutionary synthesis models of Bruzual & Charlot (1993; BC). Rather than a range of models designed to fit the Hubble sequence, we show an instantaneous burst of star formation observed at ages from 1 to 10 Gyr. There is satisfyingly little model dependence of the K-corrections. The following is a good fit to the 5-Gyr data for $z \lesssim 1.5$:

$$K(z) = \frac{-2.58z + 6.67z^2 - 5.73z^3 - 0.42z^4}{1 - 2.36z + 3.82z^2 - 3.53z^3 + 3.35z^4}, \tag{6}$$

and we use this as our standard K-correction.

For comparison, we also show the K-correction for the 'UV-hot' elliptical model of Rocca-Volmerange & Guiderdoni (1988; RVG). A good fit to their data for $z \lesssim 1.5$ is

$$K(z) = -(1 + [5z]^{-3/2})^{-2/3}. \tag{7}$$

The BC K-corrections show more structure than those from RVG, reflecting the less sophisticated treatment of infrared wavelengths by RVG. There is also a systematic difference between the BC and RVG models, of about 0.2 mag at $z = 0.5$, in the sense of RVG being bluer (although their models are redder in $R - K$). Our absolute magnitudes would thus be fainter at high redshift by this amount if we adopted the GRV K-correction. However, we are confident that the BC relation is more nearly correct, since it accounts well for the JHK colours of local galaxies (Aaronson 1978; Mobasher et al. 1993).

This completes the ingredients needed to deduce absolute magnitudes. We therefore show in Figure 9 the raw data for the luminosity function analysis: the area of the luminosity-redshift plane sampled by our survey. The following Sections analyze this distribution in order to deduce space densities.

5.3 Luminosity function estimates

The simplest estimator of the luminosity function is to bin up the data in redshift slices as a function of absolute magnitude. The estimator for the density in a given bin is then the traditional

$$\hat{\phi} = \sum_i \hat{\phi}_i = \sum_i \frac{w_i}{V(z_{\max}) - V(z_{\min})} \tag{8}$$

(Felten 1976), where $z_{\max}$ is the smaller of the maximum redshift within which a given object could have been seen, and the upper limit of the redshift band under consideration; $z_{\min}$ is the lower limit of the band. In this case, the weight to use is the full product of corrections for colour-dependent incompleteness and reduced sampling at faint K. The result is shown in Figure 10a, for redshift bins $0 - 0.2$, $0.2 - 0.4$, $0.4 - 0.8$.

An alternative way of presenting the same data has been favoured by the Hawaii group, which is to use the cumulative luminosity density. The obvious estimator for this is

$$\hat{\rho}(> L) = \sum_{L_i > L} L_i \hat{\phi}_i, \tag{9}$$

and the results are shown in Figure 10b, where luminosities have been converted to solar units on the assumption that the solar luminosity corresponds to $M_K(\odot) = 3.4$.

In both cases the message is the same, although the cumulative estimator appears (perhaps misleadingly) less noisy. While the two low-z slices are very similar, it is clear that the characteristic luminosity is higher in the

$0.4 < z < 0.8$ slice, by at least 0.5 mag. It also seems as though the overall luminosity density is very nearly constant.

We now quantify these visual impressions by model fitting. It is convenient to describe the galaxy luminosity function via a Schechter function fit at each redshift

$$d\phi = 0.921\,\phi^*(L/L^*)^{\alpha+1}\exp[-L/L^*]\,dM. \qquad (10)$$

The optimal way of fitting such models to moderate discrete datasets such as ours is to use maximum likelihood. In the absence of clustering, one would define likelihood by

$$\mathcal{L} = \prod_i \frac{d^2p}{dM\,dz}(M_i, z_i), \qquad (11)$$

and extra constraints such as operating over a redshift band can be applied by restricting the product to the relevant objects and normalizing the model probability distribution to the required region of (M, z) space.

The presence of clustering renders the vertical normalization of the luminosity function uncertain. It may also affect the shape of the function, but such luminosity segregation has never been demonstrated convincingly, and we shall assume here that it is smaller than our statistical errors. It is unclear how good this assumption is in the infrared: the known phenomenon of morphology segregation plus the tendency for ellipticals to be redder than spirals should produce some brightwards shift in characteristic luminosity – so that a positive density perturbation boosts the number density of bright galaxies in two ways. The following method at least avoids the direct density boost, and so should be closer to the average luminosity function. In the end, there is no substitute for an area which is large enough to be representative.

The above method can now be applied directly for an infinitesimal redshift band, since only the probability distribution for M at given z is involved and amplitude scalings normalize away:

$$\mathcal{L} = \prod_i \frac{dp}{dM}(M_i \mid z_i). \qquad (12)$$

This expression can be immediately generalized to a finite redshift range by continuing to use the conditional probability of M at given z – but this must now be normalized individually for each z_i of interest.

A last problem is how to deal with incompleteness. We have deduced a set of weights w_i which account for the sampling incompleteness associated with each object, so it is tempting to modify the likelihood to

$$\mathcal{L} = \prod_i \left[\frac{dp}{dM}(M_i \mid z_i)\right]^{w_i} \qquad (13)$$

(e.g. Zucca et al. 1994). However, although this would eliminate gross biases in the answer, it is clearly not satisfactory statistically. This expression corresponds to counting a few faint objects many times, so that the error bars will be characteristic of a larger sample than the real one – i.e. they will be spuriously small. The correct approach is to incorporate the incompleteness into the model:

$$\mathcal{L} = \prod_i \frac{\phi(M_i, z_i)\,C(M_i, z_i)}{\int_{-\infty}^{\infty}\phi(M, z_i)\,C(M, z_i)\,dM} \qquad (14)$$

where the completeness factor C accounts for sampling factors and magnitude limits, and is incorporated into the normalisation. It is easy to deal with our K-dependent sampling in this way. Any colour dependence is harder to deal with, however, since this does not have a direct relation with M & z. We therefore used the $\mathcal{L} \propto p^w$ prescription for the colour weights only. Since these are unity on average and have a small deviation from unity, the fact that this is not formally the correct procedure will not be a problem in practice. In fact, setting all colour weights to unity has no significant effect on our results.

This method gives a value for the characteristic luminosity in a redshift band, $L^*(z)$; the normalization $\phi^*(z)$ can then be determined from the overall numbers of objects (although it is still subject to clustering fluctuations). The errors quoted below assume that luminosity density can be measured exactly, so that the fractional error on ϕ^* is the same as that on L^*. The results of the analysis are given in Table 1, assuming $\Omega = 1$ and a Schechter-function slope of $\alpha = -1$ (letting this float yielded a best-fitting value of $\alpha = -1.04 \pm 0.31$).

Table 1. Luminosity function fits

z	$M_K^*(z)$	$\phi^*(z)/h^3$ Mpc^{-3}
$0.0 - 0.2$	-22.72 ± 0.23	0.029 ± 0.007
$0.2 - 0.4$	-22.85 ± 0.17	0.020 ± 0.003
$0.4 - 0.6$	-23.23 ± 0.23	0.013 ± 0.003
$0.6 - 0.8$	-23.68 ± 0.30	0.009 ± 0.002
$0.0 - 0.4$	-22.75 ± 0.13	0.026 ± 0.003
$0.4 - 0.8$	-23.41 ± 0.24	0.011 ± 0.003
$0.0 - 0.8$	-23.01 ± 0.11	0.019 ± 0.002

These numbers paint an interesting picture, and confirm earlier visual impressions. There indeed appears to be some evidence for luminosity evolution in the sense that M_K^* was brighter in the past. The no-evolution hypothesis is ruled out at about the 4 per cent significance level, considering the variation of M_K^* alone. On the other hand, there is no evidence for evolution for $z < 0.6$. Furthermore, there is evidence that the overall normalization of the luminosity function is a declining function of redshift.

A simple model that accounts for what is seen is therefore to take the low-z parameters for the luminosity function

$$M_K^*(0) = -22.8; \quad \phi^*(0) = 0.026h^3 \text{ Mpc}^{-3}, \qquad (15)$$

and scale them approximately as $L^* \propto (1 + z)$ and $\phi^* \propto (1 + z)^{-1}$. This looks very like the merging models advocated by Broadhurst et al. (1992), with an approximately conserved luminosity density – except that the evolution is in the opposite sense.

These results are derived on the assumption of an Einstein-de Sitter model. Since we have made aperture corrections that involve fixed metric diameters, the whole analysis should in principle be re-done from the start for any different model. However, since the aperture corrections are only important at low redshift, it will suffice to ask how the luminosity distance and volume element change for different models. To illustrate the model sensitivity, we focus on

$z = 0.7$, which is the centre of our highest-z bin. We consider two popular alternative models: (A) an open universe with $\Omega = 0.2$; (B) a $k = 0$ model with $\Omega = 0.2$ in matter and $\Omega = 0.8$ in vacuum energy. The required distances and volumes, divided by those for the Einstein-de Sitter model, are $D_L(0.7) = 1.14$ (A) and 1.32 (B); $dV(0.7) = 1.60$ (A) and 2.89 (B). Adoption of these models would thus exacerbate the trends we have identified: M^* at high redshift would be 0.3 – 0.6 mag. brighter, and ϕ^* would be a factor 1.6 – 2.9 lower. Note that the total luminosity density would decline only slightly: this is a relatively robust quantity.

Lastly, we consider the question of dependence of the luminosity function on colour. Using the colour-redshift plot of Figure 4, it is possible to divide the sample at approximate Hubble-type boundaries by simple vertical shifting of any of the model lines. We have partitioned the sample into three equal parts in this way, and galaxies of different colour are indicated by different symbols in Figure 9. Restricting attention to $z < 0.5$, where the overall sample has no evidence for evolution, we find the following M^* values (assuming $\alpha = -1$): -22.85 ± 0.18 (reddest: approximately E/Sa); -22.92 ± 0.18 (intermediate: approximately Sb); -21.32 ± 0.28 (bluest: approximately Sc/Im). There is thus a strong trend for the bluest galaxies to be less luminous. However, in agreement with Mobasher et al. (1993), we find little difference between M^* for the two reddest categories: ellipticals and early-type spirals.

5.4   Comparison to other results

These numbers are very different from the results of Mobasher et al. (1993), who (for $h = 1$) obtained $M^* = -23.6 \pm 0.3$ and $\phi^* = 0.0046 \pm 0.0011$. How can it be that we have obtained a characteristic luminosity a magnitude fainter and a normalization over 5 times higher? It sounds like there is some error, but the numbers are not as different as they seem. Mobasher et al. used isophotal magnitudes, rather than a fixed metric aperture. If we consider their objects with $z \simeq 0.1$ (the highest redshift objects, which are the most luminous and which thus dominate the determination of M^*), their median aperture is approximately $40\ h^{-1}$ kpc diameter, which immediately makes their magnitudes 0.3 mag. brighter than ours, if we adhere to the power-law aperture correction. Also, the K-corrections used are different: they adopt $K_K(z) = -0.7z + 3.9z^2$, a much weaker dependence than our $K_K(z) \simeq -2.58z$. At $z = 0.1$, the difference in K-correction is 0.22, so that this plus the aperture difference accounts for 0.52 mag. of the 0.8 mag. difference in M^*; the remaining difference is not statistically significant. As for the difference in ϕ^*, this may well be partly due to density fluctuations, but it is also possible that the Mobasher et al. sample is systematically incomplete: since their data were based on infrared measurements of blue-selected galaxies, the population of very red nearby galaxies will not be sampled adequately. If the Mobasher et al. sample is incomplete for faint K, this would produce a spuriously low normalization and a spuriously bright M^*. Mobasher et al. used a V/V_{max} test to assess completeness, but they have a very rich cluster at $z \simeq 0.04$, and so this test for completeness is invalid, since it relies on spatial homogeneity. It is also possible that any tendency towards brighter L^* in clusters might bias their result, although they failed to detect any systematic difference in the luminosity function for ellipticals. An alternative viewpoint is to worry that our L^* may be too faint because our 'blank-field' survey regions were necessarily chosen free of extremely bright objects. There are two arguments against this being important: (i) we have the same fainter L^* in the $z = 0.2 - 0.4$ bin, where the brightest objects are fainter than the positional references; (ii) luminosity function fitting to the binned data ignoring the existence of empty bright bins gives consistent L^* values.

Similarly, our results diverge quite markedly from those of the Hawaii group (Cowie et al. 1995). They obtain a total $M_K^* \simeq -23.4$, which is claimed not to evolve, and a normalization which changes approximately as $(1 + z)^2$. The local value of ϕ^* for their data is not quoted, but is approximately $0.006h^3$ Mpc^{-3}. This difference between our results and those of the Hawaii group is more disturbing, since they have a much larger area than Mobasher et al., and almost twice as many redshifts as we do. On the other hand, their sampling rate declines rapidly with K: in the region containing most of our data ($15 < K < 17$), we have 103 redshifts, whereas they have 73. The fact that we see a clear increase in L^* at high redshifts, whereas they do not, is barely consistent with limited statistics.

The difference is clearly in the raw data and *not* in the analysis: we have analysed their dataset using the method outlined in Section 5.3 and obtained identical results to Cowie et al. Much turns on the status of the rare bright galaxies at high redshift. We have 9 objects with $z > 0.6$, $K < 17$, whereas the Hawaii group have 5. Either they are missing a few objects, or we have an upward fluctuation. However, note that our method of analysis should be robust with respect to density fluctuations. One might worry about having a single rich cluster in the survey with an atypically bright L^*, and we do indeed have some kind of enhancement in number at $z \simeq 0.65$. However, the galaxies here come from two widely separated fields, and there is only one pair within a proper separation of $1\ h^{-1}$ Mpc. It therefore seems implausible that our bright L^* at $z > 0.6$ can be biased by density fluctuations. However, a larger sample is clearly required for a definitive answer.

Most odd of all is the large discrepancy in luminosity density at low redshifts between our results and those of the Hawaii group. We note that in their lowest redshift bin, $0 < z < 0.2$, Cowie et al. have a rather low normalisation for their luminosity function, equivalent to $\phi^* \simeq 0.006h^3$ Mpc^{-3}. Most workers estimate the local optical ϕ^* to lie in the range $0.01 - 0.03h^3$ Mpc^{-3} (e.g. Loveday et al.'s (1992) luminosity function analysis); these values are approximately $2 - 5$ times larger. We therefore suspect that the lowest-redshift bin of the Hawaii data may be incomplete. If this is ignored, the difference between our higher-redshift results is not so great, as discussed above.

6   IMPLICATIONS FOR FAINT COUNTS

The obvious question now is how the models which fit the data at $K \lesssim 17$ and $z \lesssim 1$ will fare when extrapolated to fainter K magnitudes and higher redshifts. Figure 11 shows the number-count data compared to selected models. The interesting thing here is how well the no-evolution

model fits the data, contrary to previous claims. As discussed above, these were made on the basis of analyses which ignored substantial aperture corrections. The counts fall below the Euclidean prediction at about the point where M^* reaches $z = 1$; since we now have a somewhat fainter M^*, the turnover moves to fainter magnitudes and matches well the observed decline of the counts. Our increased ϕ^* value means that the overall level of the counts are correctly predicted, as well as the shape. Since our redshift data only rule out the no-evolution model at a moderate level of significance, it seems that this is something that should still be taken seriously. Moving to pure $L^* \propto 1 + z$ luminosity evolution with the same local normalization now significantly exceeds the faint counts, whereas it was previously claimed to give a good match. However, conserving luminosity density by scaling $\phi^* \propto (1 + z)^{-1}$ at high redshifts restores the good fit at most magnitudes. The predicted numbers are too small at $K > 21$, but this should not be very surprising, since the typical luminosities of galaxies at that level are fainter than we have been able to probe in our luminosity function determination. One simple possibility is that the luminosity function has an extra dwarf component which makes it steeper at the faint end; several authors have argued for such a component both in cluster luminosity functions (e.g. Driver et al. 1994) and in the field (e.g. Gronwall & Koo 1995). Driver et al. obtain the following parameters for the dwarf luminosity function:

$$M^*_{\mathrm{dwarf}} = M^*_{\mathrm{normal}} + 3.5$$
$$\phi^*_{\mathrm{dwarf}} = 2\phi^*_{\mathrm{normal}} \tag{16}$$
$$\alpha_{\mathrm{dwarf}} = -1.8.$$

Adding such a (non-evolving) low-luminosity contribution to our antimerging normal luminosity function fits the faint counts with no adjustment of parameters. We therefore suggest that this combination be regarded as a 'standard model' for the infrared luminosity function.

Can these possibilities be constrained by fainter redshift data? Cowie et al. (1994) have described redshift surveys as faint as $K(6'') = 20$, and shown that the median redshift continues to follow their no-evolution prediction down to $K(6'') = 18 - 19$ ($z_{\mathrm{med}} = 0.65 \pm 0.15$), but to diverge at $K(6'') = 19 - 20$ ($z_{\mathrm{med}} = 0.5 \pm 0.2$). Our predictions for these median redshifts are 0.70 & 0.97 respectively for the no-evolution model, 0.87 & 1.17 respectively for the luminosity/density evolution model, and 0.84 & 1.02 respectively for the luminosity/density evolution model with extra dwarfs. The departure from all these models in Cowie et al.'s faint $K = 19$–20 bin is rather severe. In the context of the model that includes dwarfs, we note that Cowie et al.'s data do contain the suggestion of a low-luminosity clump around $K = 19.5 - 20$, $z \simeq 0.2$, which is where the dwarf population would first manifest itself. However, more faint redshift data are really required for a definite statement: the true median redshift in Cowie et al.'s faintest bin may well be higher than the figure they estimate from a set of 22 galaxies, of which 9 have redshifts estimated from colours.

7   CONCLUSIONS

We have presented an unbiased infrared-selected redshift survey of 124 galaxies to $K = 17.25$ and deduced the evolution of the K-band luminosity function. Our principal conclusions are

(i) That the local normalization of the luminosity function is somewhat higher than has been found in previous work: $\phi^* = 0.026 \pm 0.003\, h^3\, \mathrm{Mpc}^{-3}$.

(ii) Combined with a slightly fainter L^* than previous work, we find that an $\Omega = 1$ model with no evolution fits the number counts rather well to $K = 21$.

(iii) However, our data indicate that L^* is brighter at high redshift, by at least 0.5 mag. at $z = 0.7$.

(iv) Positive luminosity evolution in this sense then fits the counts only if (a) there is corresponding negative density evolution and (b) there is an additional dwarf component at very low luminosities.

How do we relate these results to optical studies of the galaxy population? We are unable to say much about the 'faint blue galaxies' that dominate the faint optical counts: given their colours, we would expect them to have $M_K \sim -21.5$, and at $K < 17.25$ we would not be able to see them beyond $z > 0.15$. Rather they would not manifest themselves until $K = 19$–20, and so this suggests an obvious connection between the faint excess in the blue counts and the possible dwarf population discussed above. Such an idea is given further support by the results of Glazebrook et al. (1995b), based on HST imaging of random galaxy fields. They find counts of morphologically normal ellipticals and spirals to be much as expected from no-evolution models, whereas the faint excess arises from steep number counts in the irregular population.

Nevertheless, because we favour a model in which the normalization is high, this does have implications for evolution in the optical. Various workers (e.g. Metcalfe et al. 1991; 1994) have argued for a high normalization, based on the good fit of a no-evolution model around $b_J = 19$. This would then imply that the bright counts are incomplete, by a factor of 2 at $b_J = 17$, favouring a prosaic explanation such as that of McGaugh (1994). In this sense, the implication of our result is that the faint blue galaxies may be less dominant than often supposed, and less in need of radical explanations.

Turning to the infrared luminosity function, what are the physical implications of the evolution we have detected? Our results stand in direct contradiction to the simple scaling merger model of BEG, and imply that at least the most luminous galaxies may have had a relatively uneventful history. The amount of luminosity evolution we see is consistent with what is inevitably expected from passive aging of stellar populations – a point stressed by Cowie et al.1995. The evolution of the bright end is also similar to that seen in 3CR radio ellipticals by Lilly & Longair (1984) – although see Dunlop & Peacock (1993) for evidence that the infrared light in 3CR galaxies probably has an AGN-related component.

The bright end of the luminosity function is therefore consistent with a picture in which massive spheroids were in place at $z \gtrsim 1$ and have subsequently evolved passively (see e.g. Bower et al. 1992 for other pieces of evidence in favour of this conclusion). However, we do not see a luminosity density which declines with time, as expected from passive aging alone. A possible interpretation of this fact is that additional star formation at intermediate redshifts enhances the luminosity function of lower-luminosity galaxies. In a picture where spheroids are old and passively evolving,

it would be natural to associate this feature with the epoch of disk formation (e.g. Gunn 1982). The failure of this process to affect the bright end of the luminosity function would then be related naturally to morphological segregation and the preference of the most luminous ellipticals for dense environments.

Clearly, this is only a preliminary and qualitative picture, which requires further testing and refinement. Of particular interest will be the evolution at $z > 1$, which is rather poorly constrained by existing data. This remains an outstanding task for the new generation of large telescopes.

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APPENDIX: THE SPECTROSCOPIC SAMPLE

This appendix presents details of our galaxy sample, listed in Table A1. The ID numbers correspond to those in Table 4 of Paper I. Note that, owing to an error, not all of Table 4 was printed in Paper I; details of the omitted objects are available on request from the authors.

The spectral type is denoted by a simple nomenclature where 'E' and 'A' respectively refer to whether the spectra have emission (predominantly [OII], $H\beta$ and [OIII]) and

absorption features ($H + K$, G, $H\beta$–$H\theta$). Additionally we use 'ER' to refer to spectra with strong $H\alpha$ emission where observable. A selection of the survey spectra are shown in Figure A1.

We give photometry both within 4-arcsec diameter apertures, as in paper I, and also within 20 h^{-1} kpc metric apertures. For about 10% of our objects, we were unable to measure a big enough aperture at low redshift or small enough at high redshift to reach 20 h^{-1} kpc. For these objects we extrapolate with the $r^{0.4}$ growth law – typically the extrapolations are over a small range of 20–50% in diameter and thus deviations from the $r^{0.4}$ law will be only at the $\ll 0.1$ magnitude level.

The last two columns give weights for incompleteness as a function of K and colour. The former was obtained by the ratio of the raw number counts in the sample to the mean count expected over 552 arcmin^2. The latter was obtained by dividing the $(R - K)$ – K colour–magnitude plane into cells (using increments of 0.3 in K and 0.5 in $R - K$) and comparing the populations of these cells in our total and spectroscopic samples. A colour-dependent weight was then deduced, normalised to a mean of unity at each K. Where cell populations were too low for meaningful statistics, a weight of unity was assumed.

Table A1: The K-selected spectroscopic sample

ID	RA (1950.0) DEC		z	Ty	$K_{4''}$	$K_{20h^{-1}\mathrm{kpc}}$	$R_{4''}$	$R_{20h^{-1}\mathrm{kpc}}$	w_K	w_{R-K}
11	22 38 59.55	+00 37 38.27	0.129	A	14.25 ± 0.05	13.78 ± 0.05	17.84 ± 0.04	17.05 ± 0.03	0.24	1.00
18	22 38 41.69	+00 31 49.68	0.384	A	16.43 ± 0.10	16.44 ± 0.16	20.39 ± 0.05	20.08 ± 0.04	3.93	0.81
24	22 38 37.94	+00 33 18.39	0.075	E	16.08 ± 0.11	15.42 ± 0.12	18.48 ± 0.04	17.58 ± 0.03	2.64	1.00
31	22 38 43.84	+00 33 55.83	0.666	A	15.90 ± 0.09	15.75 ± 0.12	20.20 ± 0.05	20.13 ± 0.04	2.09	1.00
54	22 38 38.45	+00 34 51.21	0.278	EA	16.96 ± 0.17	16.65 ± 0.21	20.68 ± 0.06	20.15 ± 0.05	3.17	1.33
56	22 38 34.54	+00 35 28.69	0.278	EA	16.74 ± 0.15	16.35 ± 0.19	19.87 ± 0.05	19.48 ± 0.04	2.69	0.98
66	22 40 30.26	+00 25 56.63	0.399	EA	16.92 ± 0.18	16.65 ± 0.22	20.79 ± 0.05	20.52 ± 0.04	3.17	1.29
68	22 40 31.98	+00 26 12.71	0.147	EA	16.25 ± 0.10	15.97 ± 0.18	19.00 ± 0.04	17.92 ± 0.03	2.64	1.00
73	22 40 27.78	+00 27 11.34	0.148	A	15.48 ± 0.07	15.46 ± 0.14	18.67 ± 0.04	18.55 ± 0.03	0.91	0.98
77	22 40 02.69	+00 21 34.23	0.160	A	16.31 ± 0.12	15.88 ± 0.16	19.70 ± 0.04	19.18 ± 0.03	3.93	1.21
90	22 40 12.72	+00 21 29.73	0.302	A	16.84 ± 0.18	16.88 ± 0.20	18.22 ± 0.04	18.24 ± 0.03	3.17	1.00
91	22 40 09.02	+00 21 37.83	0.191	A	15.83 ± 0.09	15.54 ± 0.14	19.00 ± 0.04	18.34 ± 0.03	2.09	1.00
95	22 40 11.48	+00 22 26.00	0.289	A	16.33 ± 0.12	16.44 ± 0.18	19.85 ± 0.04	19.68 ± 0.03	3.93	0.79
96	22 40 13.93	+00 22 32.01	0.225	E	16.04 ± 0.10	15.98 ± 0.15	21.81 ± 0.10	21.63 ± 0.09	2.64	1.00
104	22 40 18.20	+00 24 30.77	0.654	A	17.14 ± 0.20	16.84 ± 0.24	22.07 ± 0.11	21.77 ± 0.09	8.91	1.00
106	22 40 18.74	+00 24 58.85	0.801	A	16.22 ± 0.10	16.16 ± 0.10	21.70 ± 0.09	21.63 ± 0.06	2.64	1.00
109	22 40 20.59	+00 25 39.50	0.148	EA	15.42 ± 0.06	14.96 ± 0.08	19.38 ± 0.04	18.76 ± 0.03	0.91	0.86
118	22 40 15.23	+00 30 04.37	0.654	A	16.67 ± 0.15	16.71 ± 0.14	21.33 ± 0.07	21.18 ± 0.05	2.69	0.86
120	22 40 19.71	+00 30 14.37	0.210	A	15.69 ± 0.08	15.51 ± 0.12	19.00 ± 0.05	18.42 ± 0.04	0.83	0.98
121	22 40 16.51	+00 30 18.37	0.582	A	15.95 ± 0.09	15.96 ± 0.08	19.95 ± 0.04	19.64 ± 0.03	2.09	1.00
132	22 39 58.28	+00 24 46.24	0.409	E	16.82 ± 0.15	16.68 ± 0.19	20.04 ± 0.05	19.88 ± 0.04	3.17	0.98
138	22 39 37.84	+00 21 26.98	0.271	EA	16.11 ± 0.10	15.91 ± 0.13	20.12 ± 0.05	19.53 ± 0.04	2.64	1.00
146	22 39 38.01	+00 21 50.51	0.291	EA	16.75 ± 0.15	16.58 ± 0.20	19.93 ± 0.05	19.34 ± 0.03	2.69	0.98
149	22 39 33.89	+00 22 29.13	0.074	ER	15.03 ± 0.06	14.47 ± 0.11	No Data	No Data	0.63	1.00
151	22 39 40.14	+00 24 16.61	0.153	EA	15.56 ± 0.07	15.55 ± 0.14	18.49 ± 0.04	17.82 ± 0.03	0.83	1.02
159	22 39 37.16	+00 25 44.39	0.073	A	13.30 ± 0.05	12.67 ± 0.05	16.28 ± 0.04	15.10 ± 0.03	1.00	1.00
164	22 39 38.59	+00 28 33.25	0.408	EA	16.88 ± 0.17	16.51 ± 0.15	20.95 ± 0.16	20.72 ± 0.13	3.17	1.00
169	22 39 32.42	+00 31 27.18	0.150	A	15.73 ± 0.10	15.31 ± 0.10	18.94 ± 0.04	18.30 ± 0.03	0.83	0.98
173	22 39 34.22	+00 31 53.23	0.127	A	15.39 ± 0.09	14.52 ± 0.07	18.48 ± 0.04	17.31 ± 0.03	0.91	1.29
181	22 39 31.48	+00 25 00.98	0.332	EA	16.98 ± 0.18	16.47 ± 0.21	19.43 ± 0.04	18.92 ± 0.03	3.17	1.00
190	22 39 05.99	+00 22 58.60	0.387	A	15.93 ± 0.09	15.95 ± 0.12	19.82 ± 0.04	19.67 ± 0.03	2.09	1.00
198	22 38 55.21	+00 24 03.35	0.290	A	16.00 ± 0.09	15.81 ± 0.10	19.31 ± 0.04	18.83 ± 0.03	2.09	1.00
199	22 38 56.90	+00 24 14.64	0.388	EA	16.89 ± 0.17	16.88 ± 0.21	20.54 ± 0.05	20.24 ± 0.04	3.17	1.29
212	22 39 00.35	+00 29 45.16	0.179	EA	16.91 ± 0.18	16.50 ± 0.21	20.13 ± 0.07	19.47 ± 0.06	3.17	0.98
220	22 38 47.57	+00 26 21.46	0.777	A	16.78 ± 0.15	16.67 ± 0.15	21.50 ± 0.08	21.37 ± 0.07	3.17	0.86
224	22 38 39.84	+00 26 19.33	0.063	A	16.20 ± 0.11	15.79 ± 0.15	20.01 ± 0.04	19.48 ± 0.05	2.64	0.79
226	22 38 39.41	+00 26 32.98	0.358	EA	17.15 ± 0.20	16.77 ± 0.22	20.80 ± 0.06	20.42 ± 0.04	8.91	1.33
229	22 38 39.37	+00 27 32.27	0.503	A	16.62 ± 0.13	16.39 ± 0.15	20.33 ± 0.05	19.76 ± 0.05	2.69	0.81
244	22 38 37.48	+00 29 50.20	0.442	A	16.61 ± 0.18	16.34 ± 0.21	20.29 ± 0.05	20.02 ± 0.03	2.69	0.81
250	22 38 53.87	+00 20 58.55	0.658	E	16.52 ± 0.17	16.41 ± 0.22	22.22 ± 0.12	22.15 ± 0.09	2.69	1.00
253	22 39 03.52	+00 22 30.43	0.301	A	15.13 ± 0.07	15.09 ± 0.09	18.85 ± 0.04	18.60 ± 0.03	0.63	1.00
259	22 38 50.30	+00 29 11.81	0.276	EA	16.20 ± 0.14	16.05 ± 0.21	19.72 ± 0.05	19.22 ± 0.03	2.64	0.79
265	00 52 10.66	+00 15 35.34	0.207	A	14.73 ± 0.05	14.22 ± 0.06	18.03 ± 0.04	17.45 ± 0.03	1.26	1.00
267	00 52 06.99	+00 15 54.34	0.205	A	15.80 ± 0.08	15.49 ± 0.12	18.79 ± 0.04	18.34 ± 0.03	2.09	1.00
281	00 52 29.84	+00 16 48.97	0.210	ER	16.97 ± 0.16	16.63 ± 0.22	19.42 ± 0.04	19.08 ± 0.03	3.17	1.00
285	00 52 34.76	+00 20 19.43	0.067	E	15.56 ± 0.08	15.01 ± 0.13	18.14 ± 0.04	17.39 ± 0.03	0.83	1.02
288	00 52 37.75	+00 15 38.02	0.146	ER	15.57 ± 0.07	14.97 ± 0.10	18.60 ± 0.04	17.62 ± 0.03	0.83	0.98
291	00 52 13.80	+00 23 32.68	0.380	E	16.96 ± 0.20	16.82 ± 0.20	20.36 ± 0.05	20.16 ± 0.04	3.17	0.67
293	00 52 15.23	+00 23 49.49	0.377	A	15.52 ± 0.08	15.28 ± 0.07	18.76 ± 0.04	18.50 ± 0.03	0.83	0.98
295	00 52 14.31	+00 23 56.77	0.236	A	15.36 ± 0.07	14.95 ± 0.07	18.42 ± 0.04	18.00 ± 0.03	0.91	1.29

ID	RA (1950.0) DEC	z	Ty	$K_{4''}$	$K_{20h^{-1}\mathrm{kpc}}$	$R_{4''}$	$R_{20h^{-1}\mathrm{kpc}}$	w_K	w_{R-K}
297	00 52 04.75 +00 20 52.75	0.067	ER	15.43 ± 0.07	14.16 ± 0.08	18.05 ± 0.04	16.01 ± 0.03	0.91	0.86
300	00 52 09.76 +00 21 30.25	0.087	EA	16.04 ± 0.09	15.09 ± 0.11	18.34 ± 0.04	16.91 ± 0.03	2.64	1.00
302	00 52 08.35 +00 21 48.30	0.086	E	14.18 ± 0.05	13.48 ± 0.06	16.95 ± 0.04	16.02 ± 0.03	0.37	1.00
312	00 52 20.15 +00 24 14.74	0.236	A	14.97 ± 0.06	14.77 ± 0.06	18.51 ± 0.04	18.12 ± 0.03	1.87	1.00
313	00 52 17.60 +00 24 20.68	0.235	A	16.25 ± 0.10	16.07 ± 0.18	19.63 ± 0.05	19.30 ± 0.04	2.64	1.21
314	00 52 21.87 +00 24 29.16	0.471	A	17.02 ± 0.18	16.82 ± 0.22	20.06 ± 0.05	19.86 ± 0.04	8.91	0.67
316	00 52 25.49 +00 20 11.44	0.676	A	16.80 ± 0.13	16.71 ± 0.18	21.50 ± 0.09	21.42 ± 0.07	3.17	0.86
317	00 52 24.21 +00 20 29.08	0.124	A	15.20 ± 0.06	14.89 ± 0.07	17.94 ± 0.04	17.51 ± 0.03	0.63	0.86
319	00 52 25.52 +00 20 39.10	0.546	EA	16.92 ± 0.16	16.79 ± 0.21	20.41 ± 0.06	20.28 ± 0.05	3.17	0.98
320	00 52 24.81 +00 20 45.78	0.124	E	16.63 ± 0.12	16.09 ± 0.20	18.79 ± 0.04	17.67 ± 0.03	2.69	1.00
321	00 52 16.03 +00 18 58.77	0.217	EA	16.50 ± 0.13	16.48 ± 0.21	20.14 ± 0.05	19.98 ± 0.04	3.93	0.81
323	00 52 17.10 +00 19 55.94	0.321	E	16.93 ± 0.17	16.49 ± 0.21	19.20 ± 0.04	18.60 ± 0.03	3.17	0.86
329	00 52 27.57 +00 21 23.25	0.153	A	15.75 ± 0.10	15.53 ± 0.18	19.33 ± 0.04	18.81 ± 0.03	0.83	1.00
333	00 52 46.55 +00 10 49.16	0.417	A	16.86 ± 0.17	16.64 ± 0.19	20.65 ± 0.05	20.59 ± 0.04	3.17	1.29
334	00 52 47.79 +00 10 52.72	0.192	A	15.83 ± 0.08	15.62 ± 0.12	19.80 ± 0.04	18.48 ± 0.03	2.09	1.00
336	00 52 48.07 +00 11 11.93	0.193	EA	16.57 ± 0.13	16.48 ± 0.18	19.99 ± 0.04	19.63 ± 0.03	2.69	1.19
337	00 52 48.86 +00 11 18.85	0.577	A	16.38 ± 0.12	16.27 ± 0.11	19.53 ± 0.04	19.37 ± 0.03	3.93	1.19
340	00 52 48.71 +00 11 51.46	0.636	A	15.59 ± 0.07	15.47 ± 0.07	19.86 ± 0.04	19.71 ± 0.03	0.83	1.00
341	00 52 42.98 +00 12 12.43	0.344	EA	16.66 ± 0.14	16.43 ± 0.14	19.82 ± 0.04	19.57 ± 0.03	2.69	0.98
346	00 53 10.28 +00 10 42.10	0.102	A	16.59 ± 0.13	15.69 ± 0.18	20.06 ± 0.05	19.38 ± 0.06	2.69	1.19
349	00 53 11.74 +00 11 38.97	0.154	EA	16.56 ± 0.12	15.96 ± 0.13	19.13 ± 0.04	18.05 ± 0.03	2.69	1.00
354	00 53 12.64 +00 05 48.91	0.153	A	14.29 ± 0.05	13.66 ± 0.05	17.80 ± 0.04	17.00 ± 0.03	0.24	1.00
355	00 53 08.76 +00 05 55.12	0.071	E	16.68 ± 0.15	16.21 ± 0.17	18.88 ± 0.04	18.41 ± 0.03	2.69	0.86
356	00 53 09.54 +00 06 05.00	0.209	A	15.08 ± 0.06	14.84 ± 0.08	18.27 ± 0.04	17.87 ± 0.03	0.63	1.00
358	00 53 16.43 +00 06 08.82	0.495	A	16.15 ± 0.10	15.95 ± 0.09	19.73 ± 0.04	19.50 ± 0.03	2.64	0.79
360	00 52 48.99 +00 09 26.06	0.673	A	17.24 ± 0.21	17.20 ± 0.27	22.00 ± 0.11	21.96 ± 0.08	8.91	1.00
362	00 52 47.71 +00 09 43.32	0.505	EA	17.10 ± 0.18	17.11 ± 0.20	20.18 ± 0.04	20.09 ± 0.03	8.91	0.67
363	00 52 46.35 +00 10 04.23	0.663	A	16.32 ± 0.10	15.96 ± 0.08	19.36 ± 0.04	18.92 ± 0.03	3.93	1.21
364	00 52 47.10 +00 10 19.78	0.431	A	16.58 ± 0.12	16.46 ± 0.13	20.14 ± 0.04	19.92 ± 0.03	2.69	0.81
374	00 52 51.40 +00 05 29.65	0.044	EA	16.92 ± 0.18	15.69 ± 0.20	19.04 ± 0.04	17.53 ± 0.03	3.17	0.86
378	00 52 51.47 +00 07 28.52	0.113	EA	17.10 ± 0.20	16.21 ± 0.19	19.70 ± 0.04	18.81 ± 0.03	8.91	1.00
380	00 52 52.22 +00 07 45.79	0.734	A	17.19 ± 0.20	17.06 ± 0.32	22.65 ± 0.19	22.52 ± 0.18	8.91	1.00
385	00 52 59.56 +00 09 44.62	0.045	A	14.35 ± 0.05	12.70 ± 0.05	16.82 ± 0.04	15.14 ± 0.03	0.24	1.00
387	00 53 02.15 +00 09 46.91	0.675	A	16.88 ± 0.16	16.71 ± 0.26	20.85 ± 0.13	20.68 ± 0.13	3.17	1.29
392	00 53 07.44 +00 07 15.48	0.153	EA	16.24 ± 0.10	16.12 ± 0.15	20.18 ± 0.05	19.79 ± 0.04	2.64	0.79
400	00 53 11.97 +00 13 25.19	0.192	A	17.21 ± 0.19	16.81 ± 0.26	20.46 ± 0.06	20.06 ± 0.06	8.91	0.67
405	01 53 01.29 +00 41 51.41	0.080	ER	15.73 ± 0.09	15.04 ± 0.09	18.50 ± 0.04	17.19 ± 0.03	0.83	1.02
406	01 53 05.36 +00 42 32.46	0.121	A	14.28 ± 0.05	13.78 ± 0.07	18.18 ± 0.04	17.10 ± 0.03	0.24	1.00
411	01 53 28.63 +00 46 32.36	0.085	A	14.43 ± 0.06	13.86 ± 0.07	17.39 ± 0.04	16.73 ± 0.03	0.24	1.00
418	01 53 31.84 +00 45 49.69	0.079	A	15.05 ± 0.07	14.53 ± 0.10	17.74 ± 0.04	17.13 ± 0.03	0.63	1.00
422	01 53 21.37 +00 46 21.86	0.113	A	15.66 ± 0.07	15.48 ± 0.10	19.15 ± 0.04	18.94 ± 0.04	0.83	0.98
423	01 53 20.49 +00 46 52.46	0.080	A	15.27 ± 0.06	14.88 ± 0.19	17.95 ± 0.04	17.37 ± 0.03	0.91	0.86
425	01 53 24.68 +00 44 39.93	0.080	A	14.68 ± 0.05	13.76 ± 0.07	17.51 ± 0.04	16.44 ± 0.03	1.26	1.00
431	01 53 21.72 +00 41 17.11	0.076	ER	15.67 ± 0.09	15.11 ± 0.21	18.13 ± 0.04	16.76 ± 0.03	0.83	1.00
432	01 53 20.86 +00 41 57.87	0.080	ER	15.42 ± 0.08	14.67 ± 0.09	18.04 ± 0.04	17.19 ± 0.03	0.91	0.86
434	01 53 31.18 +00 43 20.30	0.080	A	14.23 ± 0.05	13.91 ± 0.06	17.25 ± 0.04	16.77 ± 0.03	0.37	1.00
454	01 53 13.88 +00 43 58.12	0.376	A	16.82 ± 0.13	16.66 ± 0.21	20.28 ± 0.05	20.17 ± 0.04	3.17	0.98
455	01 53 13.50 +00 44 41.53	0.206	A	15.77 ± 0.07	15.60 ± 0.11	18.77 ± 0.04	18.65 ± 0.03	2.09	1.00
457	01 53 14.85 +00 45 01.44	0.551	A	17.10 ± 0.17	16.93 ± 0.27	20.83 ± 0.06	20.66 ± 0.04	8.91	1.33
462	01 53 12.42 +00 40 35.81	0.080	A	15.22 ± 0.08	14.28 ± 0.10	17.95 ± 0.04	16.22 ± 0.03	0.63	0.86
469	01 52 48.85 +00 39 51.71	0.554	A	15.57 ± 0.09	15.49 ± 0.10	18.50 ± 0.04	18.39 ± 0.03	0.83	1.02
491	01 52 35.55 +00 36 27.18	0.474	A	15.63 ± 0.07	15.43 ± 0.08	19.34 ± 0.04	19.13 ± 0.03	0.83	1.00
502	01 52 45.28 +00 22 33.32	0.403	A	16.15 ± 0.10	15.90 ± 0.11	19.93 ± 0.04	19.61 ± 0.03	2.64	0.79
506	01 52 44.12 +00 23 21.20	0.290	A	16.43 ± 0.12	16.28 ± 0.10	19.46 ± 0.04	19.31 ± 0.03	3.93	1.19

ID	RA	(1950.0)	DEC	z	Ty	$K_{4''}$	$K_{20h^{-1}\mathrm{kpc}}$	$R_{4''}$	$R_{20h^{-1}\mathrm{kpc}}$	w_K	w_{R-K}
510	01 52 52.08	+00 29 46.18	0.088	ER	15.23 ± 0.06	14.83 ± 0.09	17.96 ± 0.04	17.31 ± 0.03	0.63	0.86
511	01 52 49.82	+00 29 47.50	0.471	EA	16.66 ± 0.12	16.56 ± 0.20	20.48 ± 0.05	20.17 ± 0.03	2.69	1.29
517	01 52 45.72	+00 27 46.09	0.131	ER	14.85 ± 0.05	14.40 ± 0.07	18.22 ± 0.04	17.51 ± 0.03	1.87	1.00
520	01 52 51.65	+00 26 07.60	0.252	EA	16.63 ± 0.12	16.23 ± 0.17	20.03 ± 0.05	19.58 ± 0.04	2.69	1.19
521	01 52 50.02	+00 26 30.46	0.140	EA	16.68 ± 0.12	16.24 ± 0.21	18.97 ± 0.04	18.16 ± 0.03	2.69	0.86
525	01 52 55.08	+00 25 07.90	0.339	EA	17.00 ± 0.18	16.77 ± 0.18	20.19 ± 0.05	19.97 ± 0.04	3.17	0.67
540	01 52 27.74	+00 24 32.90	0.190	A	15.63 ± 0.07	15.27 ± 0.08	18.58 ± 0.04	17.90 ± 0.03	0.83	1.02
558	01 52 41.29	+00 28 27.72	0.119	A	15.43 ± 0.07	14.25 ± 0.07	17.80 ± 0.04	16.48 ± 0.03	0.91	1.00
561	01 52 39.81	+00 29 05.68	0.113	A	16.27 ± 0.10	15.43 ± 0.14	18.78 ± 0.04	18.07 ± 0.03	3.93	1.00
563	01 52 36.76	+00 25 14.35	0.080	ER	14.40 ± 0.05	13.73 ± 0.06	18.09 ± 0.04	16.73 ± 0.03	0.24	1.00
564	01 52 37.05	+00 25 30.23	0.339	A	16.92 ± 0.16	16.44 ± 0.21	19.70 ± 0.04	19.17 ± 0.03	3.17	1.00
568	01 52 24.55	+00 31 17.28	0.156	A	14.38 ± 0.05	13.99 ± 0.07	18.04 ± 0.04	17.56 ± 0.03	0.24	1.00
571	01 52 38.20	+00 39 55.06	0.169	A	15.20 ± 0.08	14.78 ± 0.11	18.50 ± 0.04	18.20 ± 0.03	0.63	1.29
574	01 52 46.01	+00 32 37.12	0.286	A	15.16 ± 0.06	14.72 ± 0.07	18.78 ± 0.04	18.23 ± 0.03	0.63	0.86
576	01 52 44.69	+00 31 30.01	0.287	A	15.42 ± 0.08	15.34 ± 0.12	19.32 ± 0.04	18.48 ± 0.03	0.91	0.86
1445	13 42 05.07	+00 09 32.74	0.255	A	17.19 ± 0.27	16.89 ± 0.35	20.30 ± 0.05	20.00 ± 0.04	8.91	0.67
1446	13 42 08.32	+00 09 56.45	0.370	A	16.45 ± 0.15	16.24 ± 0.14	20.52 ± 0.05	20.31 ± 0.04	3.93	1.00
1450	13 42 05.43	+00 10 26.78	0.430	E	16.68 ± 0.18	16.50 ± 0.30	20.54 ± 0.05	20.36 ± 0.04	2.69	1.29
1459	13 42 03.58	+00 05 40.13	0.408	EA	16.50 ± 0.14	16.31 ± 0.12	20.15 ± 0.05	19.96 ± 0.04	2.69	0.81
1550	13 41 54.03	+00 05 02.38	0.088	A	14.19 ± 0.05	13.64 ± 0.06	17.01 ± 0.03	16.18 ± 0.03	0.37	1.00

FIGURE CAPTIONS

Figure 1   (a) The $R - K$ vs K colour-magnitude plane for our survey. The open circles show all the data, with spectroscopic sample members being indicated by solid points. Data from both March and October fields are included, although a correction to the former is made so that the magnitudes refer to 4-arcsec diameter apertures (see section 3). Brightwards of the spectroscopic selection at $K = 17.25$, the sampling of colour at fixed K is very close to uniform.
(b) The same as panel (a), but now the points repesent all galaxies, the open circles show the 16 unidentified spectra which are brighter than the appropriate optical completeness limits defined for the spectroscopic runs, and the solid circles show the 8 identified spectrscopic galaxies which lie *fainter* than the completeness limits. These are almost all within 0.5 mag. of the relevant optical limit; our assumption is that these are merely slightly degraded versions of our successful spectra, and that their omission does not bias the results.

Figure 2   Redshift against K magnitude for the spectroscopic sample. Note that the sample probes to substantial redshifts $z_{\max} = 0.8$, and that the high-redshift bins contain a number of relatively bright galaxies, as bright at $K \simeq 15.5$ at $z = 0.6$.

Figure 3   The difference between our published 4 arcsecond K magnitudes and the new direct determinations of the magnitudes in a 20 h^{-1} Mpc aperture. The error bars are those for the larger aperture measurement. The solid line shows the behaviour expected for the adopted $r^{0.4}$ growth curve. This simple a priori model is an excellent fit to the data, and clearly introduces systematic errors no larger than about 0.1 mag.

Figure 4   The $R - K$ vs z colour-redshift distribution. The different lines show the loci of the old Burst model (providing a red envelope for ellipticals) and Hubble Sc and Im types from Rocca-Volmerange & Guiderdoni (1988). Also shown for comparison (dashed) is the old Burst model from Bruzual & Charlot (1993).

Figure 5   The K-band number counts, normalized to the usual Euclidean slope. The smooth analytic fit described in the text is statistically consistent with all the measurements, showing that the counts are well determined. All data have been corrected to 4-arcsec diameter aperture magnitudes, as described in the text.

Figure 6   The 'completeness' of our spectroscopic sample, expressed as a ratio of the observed number of galaxies in a bin to the number predicted by our count fitting formula for 552 arcmin^2. We assume that the redshift distribution at given K is unbiased in our sample, and that the sampling fraction shown here may be used to correct our sample to be representative of one complete to $K = 17.25$. Note that the apparently unphysical values exceeding unity are reasonable: some bright galaxies were inadvertently selected as astrometric reference 'stars', so these bins are biased high.

Figure 7   The histograms of redshift for our data. The raw numbers are shown in (a) and (b) gives the result after weighting galaxies to allow for K-dependent sampling.

Figure 8   The K-corrections for the Bruzual & Charlot models. The different lines show the behaviour for a delta-function burst of star formation at different ages, from 1 to 10 Gyr. We shall use the 5 Gyr model as the default K-correction. The satisfyingly near-universal predicted spectral shape in the near-infrared is well evident in this plot. Also shown (dashed) is the UV-hot elliptical model of Rocca-Volmerange & Guiderdoni (1988).

Figure 9   The redshift-magnitude data of figure 2, translated to the redshift-absolute magnitude plane. There is a smooth increase of the maximum luminosity sampled with redshift. However, in order to determine whether this corresponds to an increasing characteristic luminosity, a full luminosity function analysis is required to take account of the sampling volumes as a function of redshift. The different symbols correspond to three equal classes of restframe colour: filled circles denote E/Sa; open circles Sb; crosses Sc/Im. Note the fainter characteristic luminosity of the last class.

Figure 10   The luminosity function results, expressed in two ways: (a) the binned luminosity function; (b) the cumulative luminosity density, assuming $M_K(\odot) = 3.4$. Both these methods make the point that there is little evidence for evolution in the luminosity function out to $z = 0.4$. At $0.4 < z < 0.8$, however, the characteristic luminosity is $0.5 - 1$ mag. brighter, with some suggestion that the characteristic density has declined.

Figure 11   The K-band number counts, normalized to the usual Euclidean slope. The plotting symbols have the same

meanings as in Figure 5. The various solid lines show different models based on our low-redshift luminosity function results, all assuming $\Omega = 1$. Panel (a) shows that no evolution fits the data rather well, in contrast to our earlier predictions based on a brighter L^* and lower ϕ^*. Panel (b) shows that pure luminosity evolution exceeds the faint counts. Luminosity evolution with declining normalization at high redshift fits better, but the predicted counts are too low in the faintest bins. Including a (non-evolving) dwarf component to the local LF as in Driver et al. (1994) provides a good fit.

Figure A1   Plots of a random selection of spectra from the survey. The positions of standard spectral features are indicated for the adopted redshift.

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